CONFORMAL TRANSDUCERS AND KISTLER 6203 TRANSDUCERS FOR MEASURING CHAMBER GAS PRESSURE IN SMALL ARMS AMMUNITION

AR-006-873

C. WACHSBERGER AND S. FORBES

MRL-TN-608

MATERIALS RESEARCH LABORATORY

DSTO

A Comparison between Conformal Transducers and Kistler 6203 Transducers for Measuring Chamber Gas Pressure in Small Arms Ammunition

C. Wachsberger and S. Forbes

MRL Technical Note
MRL-TN-608

Abstract

Today, copper crusher gauges have largely given way to quartz piezoelectric transducers for the measurement of pressure in small calibre gun firings. Recent developments in piezoelectric transducers have resulted in the creation of the conformal gauge. This device, fitted semi-permanently in the proof barrel, measures gas chamber pressure by directly sensing the resultant forces on the cartridge case. This report gives results of comparisons made between PCB type 117B conformal transducers and NATO approved Kistler 6203 transducers for the measurement of pressure of 7.62 mm and 5.56 mm calibre NATO ammunition in proof barrels.

DSTO MATERIALS RESEARCH LABORATORY

Published by

Materials Research Laboratory
Cordite Avenue, Maribyrnong
Victoria, 3032 Australia

Telephone: (03) 246 8111
Fax: (03) 246 8999

AR No. 006-873

APPROVED FOR PUBLIC RELEASE

Contents

A Comparison between Conformal Transducers and Kistler 6203 Transducers for Measuring Chamber Gas Pressure in Small Arms Ammunition

1. *Introduction*

NATO approved Kistler 6203 transducers are often used to measure the chamber gas pressure developed during gun firings. In order to measure the full combustion cycle when using this system, cartridge cases have to be drilled prior to firing and inserted into the chamber of the barrel such that proper alignment of the drilled hole with the transducer measuring port is maintained. Failure to do so can result in errors in measurement over and above those which occur as a result of an imperfect gas seal between the walls of the case and the chamber.

A new piezoelectric alternative, the conformal transducer, eliminates these problems as it is fitted semi-permanently in the barrel and utilizes the cartridge case as a protective diaphragm.

In the work described here, experiments were conducted at Materials Research Laboratory with PCB type 117B charge-coupled conformal transducers configured for use with 5.56 mm and 7.62 mm ammunition. Their performance was assessed against Kistler 6203 transducers and in particular the effect of cartridge case variations on their response was determined. The Kistler 6203 transducers were positioned at the chamber (to measure in-case pressure) and at the case mouth locations. This technical note presents and discusses the results of these assessments.

2. *Description*

The transducer [1] consists of a quartz sensing element which is constrained within a cylindrical steel housing embodying a thick and rigid end cap (Fig. 1). The end cap is kept in intimate contact with the element at all pressures to reduce the effects of resonance. The outer surface of the end cap is curved to conform to the circumference of the cartridge case with which it remains in contact during a gun firing. The cartridge case expands with the rapidly rising gas pressure thus

transmitting a force to the quartz element. The element generates a charge which is ultimately translated into a pressure reading.

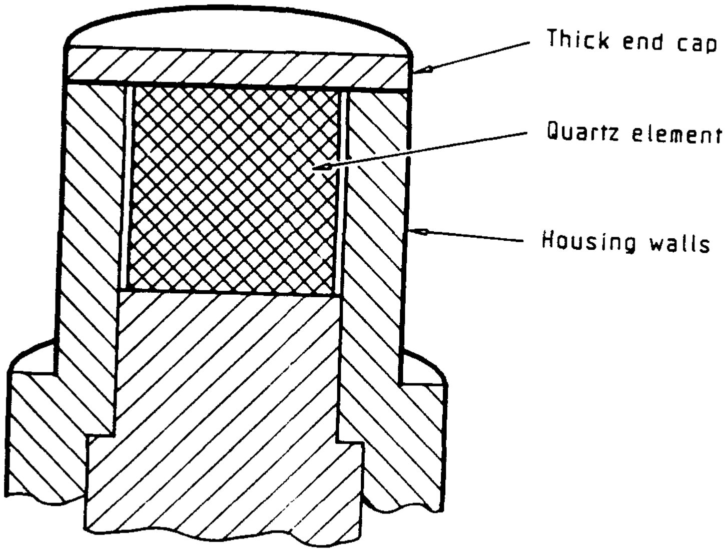

Figure 1: Diagrammatic representation of an Integral Piston.

The 117B transducer is shown in detail in Figure 2. A bar is fixed to the top half of the transducer body to support a guide pin. The pin fits into a recess located either fore or aft of the transducer mounting hole to enable alignment of the curvature of the piston with that of the chamber. The transducer is retained in the barrel by a captive externally threaded sleeve and is mounted such that the surface of the piston is flush with the walls of the chamber.

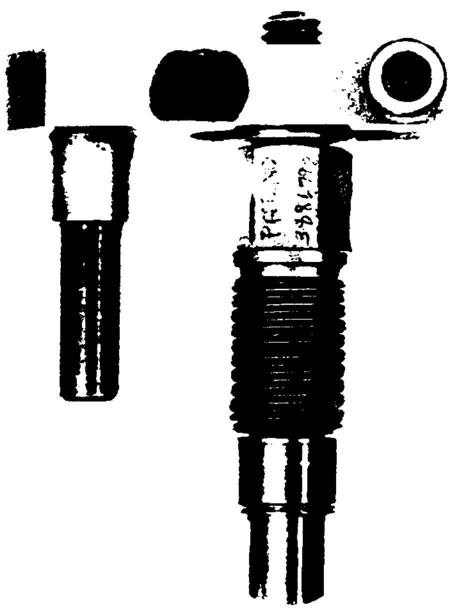

Figure 2: The 117B Conformal Transducer.

3. *Experimental*

3.1 Ammunition Selection

As the output from a conformal transducer in a gun firing depends on the rate at which the cartridge case deforms under pressure, it might be expected that the physical properties and thickness of the case material would influence the results. To test this, experiments were designed around the use of a wide selection of ammunition encompassing a number of different manufacturers and lot numbers. Details of the cases tested are shown in Tables 1 and 2.

Table 1: *7.62 mm Case Analysis*

Cartridge Case Details	Thickness (mm)				Hardness (Vickers No.)	
	mean	std. dev.	min	max	min	max
OFN military 1970	0.67	0.12	0.49	0.90	18.0	22.1
Portuguese military	0.70	0.12	0.55	0.89	19.7	20.6
OFV (Indian) military 1982	0.92	0.26	0.54	1.40	27.9	29.7
NORMA Sport	0.48	0.03	0.46	0.52	25.8	26.6
PMC Sport	0.50	0.01	0.48	0.54	27.8	27.9
MF (Munitions Factory Aust) military 1983	0.58	0.06	0.52	0.71	17.0	18.7
Winchester Sport	0.42	0.02	0.39	0.45	20.5	21.3
Remington Sport	0.44	0.02	0.42	0.49	23.3	23.5
RWS Sport	0.51	0.01	0.50	0.53	25.4	25.8
AFF (Aust) military (centre flash hole)	0.55	0.01	0.52	0.57	21.9	23.2
AFF military 1989 (twin flash hole)	0.57	0.04	0.52	0.64	17.3	18.0

Table 2: *5.56 mm Case Analysis*

Cartridge Case Details	Thickness (mm)				Hardness (Vickers No.)	
	mean	std. dev.	min	max	min	max
Hornady Sport	0.43	0.04	0.36	0.48	34.8	35.1
CJ Military	0.48	0.07	0.37	0.57	25.1	27.4
Malaysian military 1980	0.65	0.14	0.41	0.90	23.2	26.0
Winchester Sport	0.45	0.09	0.36	0.61	30.9	31.9
PMC Sport	0.40	0.05	0.35	0.51	25.6	29.7
PMC military Lot #5-858	0.43	0.08	0.37	0.65	23.0	32.7
WCC military 1983	0.49	0.14	0.36	0.80	28.9	29.2
AFF military 1989	0.42	0.02	0.40	0.45	22.2	25.8
FNB military 1987	0.48	0.01	0.46	0.50	25.4	29.7

The above measurements were carried out on eight cases randomly selected from each group. Case hardness was assessed using the Vickers Diamond Pyramid Hardness test procedure and wall thickness was measured at four equidistant points in the region where the conformal transducer would make contact. These measurements were made with a purpose designed micrometer (see Fig. 3).

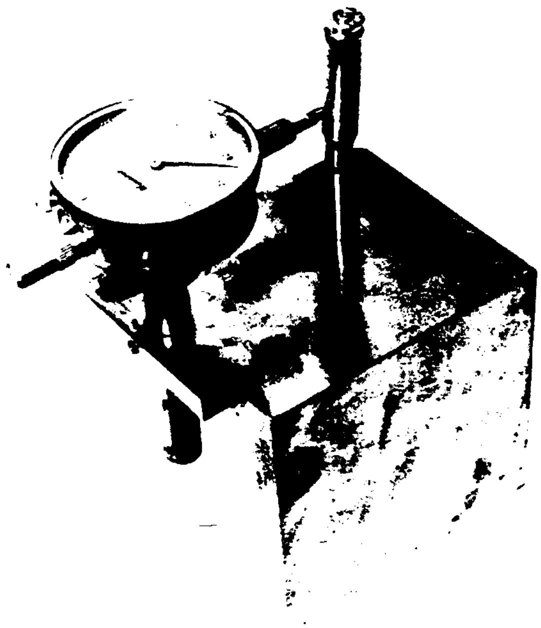

Figure 3: Micrometer used to measure cartridge case thickness.

It was decided on the basis of these results (and also on the fact that some brands were not available in sufficient numbers for the experiments) to choose the following cartridges for the main testing program:

In 7.62 mm –	PMC Sport (hardest) MF military 1983 (softest) WIN Sport (thinnest) OFV Indian 1982 (thickest)
In 5.56 mm –	AFF military 1989 (softest and thinnest) WIN Sport (hardest and thickest)

3.2 Calibration

Calibration of the Kistler 6203 transducers was performed with the use of an Aminco oil pressure balance in the manner described in Appendix 3. The conformal transducers used in these tests were originally calibrated by the manufacturer (PCB) by directly exposing the sensing surface to a static high pressure oil environment [2]. A preferred technique used at MRL utilizes a fired cartridge case into which oil is

pumped under pressure and then rapidly released. The transducer piston bears on the case as it would during an actual firing and there is a dynamic aspect to the calibration. However it is doubtful that this process accurately reflects differences in hardness and case wall thickness. Notwithstanding this possible shortcoming, the calibrations were performed by this method.

The transducer calibrating mount, which was made locally, is shown in Figure 4. It comprises a body to house the transducer and cartridge case, a threaded plug to hold the case in place, a hollow stem which permits the passing of oil into the case (which is sealed to the case neck with the aid of a rubber "O" ring) and a nut which holds the stem in the main body. A separate mount was required for each of the two calibres. High pressure oil was supplied from an Aminco pressure balance (Cat No. 47-12915).

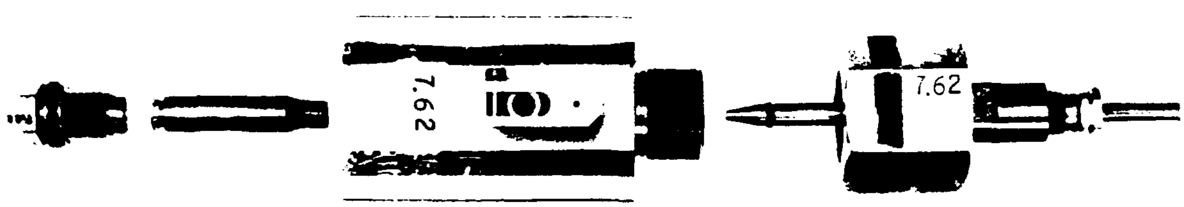

Figure 4: Transducer Calibrator.

Calibrations were performed on four 117B transducers (two for each calibre) using two representative cases of each calibre from each chosen brand/type. Pressures of 105 MPa, 140 MPa, 210 MPa, 280 MPa, 315 MPa, 385 MPa, and 420 MPa were used.

The effect of the reluctance of the case to deform in response to the pressure is evident from Figure 5. This shows that at low pressure, the strength of the case is a significant factor (particularly in 5.56 mm) in the containment of the pressure but above about 200 MPa this effect becomes of little consequence. Since normal gun pressures are well above this level the non linear characteristic is considered to be unimportant in the use of these transducers.

Table 3 shows the average charge amplifier sensitivity settings which had been determined with the Aminco pressure balance. The calculation of average sensitivities for the 5.56 mm calibre cases only used the results obtained from 210 MPa to 420 MPa because of the non linearity seen in applied pressures below 200 MPa. It appears that minor variations in transducer sensitivity exist with thick and hard cases exhibiting the lowest sensitivity. More extensive tests would be required to fully explore the relationship but the small size of the variation and the doubtful relevance of the technique to the measurement of pressure in a gun make this a low priority exercise.

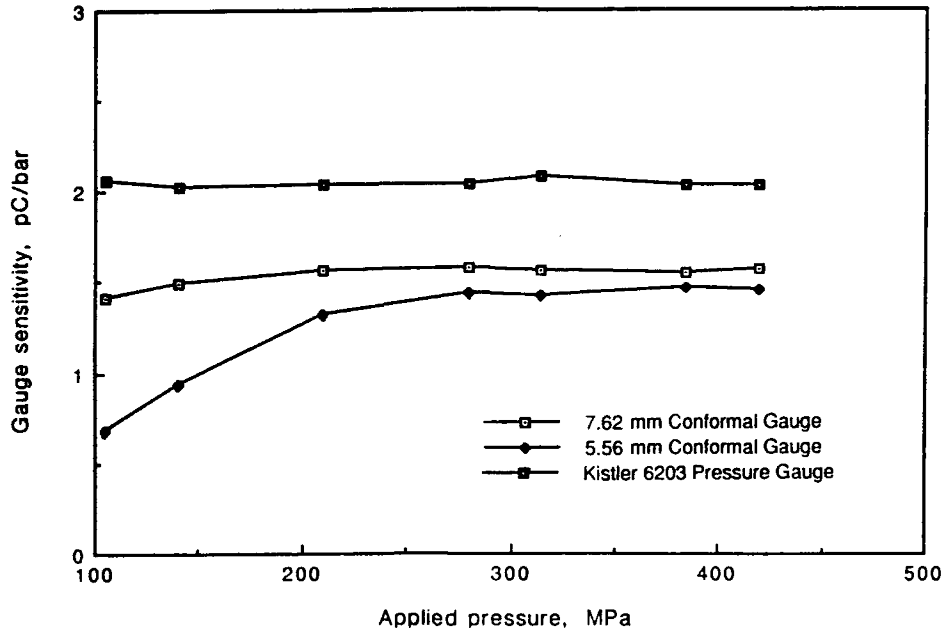

Figure 5: Transducer Linearity.

Table 3: Pressure balance calibration results

Calibre	Transducer Serial No.	Cartridge Case Details	Average Sensitivity (total sampling) pC/bar
7.62 mm	650	MF Military 83	1.49
		Winchester Sport	1.48
		PMC Sport	1.46
		OFV Indian 82	1.43
7.62 mm	649	MF Military 83	1.55
		Winchester Sport	1.56
		PMC Sport	1.55
		OFV Indian 82	1.51
5.56 mm	648	AFF Military 89	1.46
		Winchester Sport	1.37
5.56 mm	647	AFF Military 89	*N/A
		Winchester Sport	1.58

* AFF Military 89 not completed with S/N 647 due to problems arising from mechanical failures with the Aminco pressure balance at that time.

3.3 Barrel Configuration

Gun firings were performed in heavy walled barrels. A Kistler 6203 transducer was positioned diametrically opposite the conformal to measure in-case pressure. In some cases a Kistler transducer was also positioned further up the barrel to measure

case-mouth pressure (see Fig. 6). The Kistler transducers were installed according to the instructions given by the manufacturer [3]. Tests performed using the in-case Kistler necessitated the drilling of cartridge cases prior to firing. A second barrel in each calibre was machined to accept two conformal transducers positioned diametrically opposite each other.

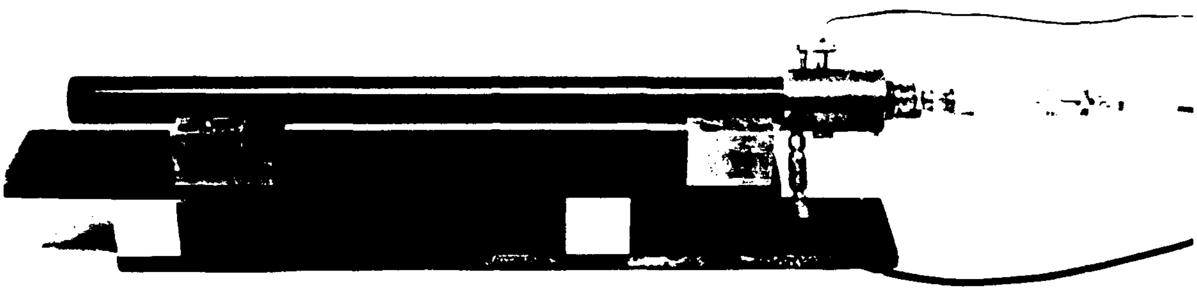

Figure 6: Heavy walled instrumented barrel.

3.4 Ammunition Configuration

All 7.62 mm cartridges were loaded with AR2206 propellant and 144 grain full metal jacket projectiles. A propellant load of 2.75 g yielded a velocity in the order of 860 m/s and a chamber pressure of about 360 MPa. Reduced fillings of 90, 80, 70, 60, 50 and 40 percent were used to achieve a range of pressures. Similarly the 5.56 mm cartridges were loaded with AR2210 propellant and SS109 projectiles. A propellant load of 1.65 g produced a velocity of 910 m/s and a chamber pressure of about 360 MPa. As in the case of 7.62 mm ammunition, filling weights were reduced to give a range of chamber pressures.

A graph showing results of some of these firings using only one conformal transducer is shown in Figure 7 (additional 7.62 mm firing data are available in Appendix 1). A shortage of OFV Indian cartridges prevented the testing of them in this configuration.

Typical conformal and in-case Kistler pressure/time curves for 7.62 mm ammunition are shown in Figure 8. The slight mismatch in-peak pressure may be as the result of slight sensitivity variations between charge amplifiers as a different amplifier had to be used in testing to the one that was used during the calibration process. The conformal transducer exhibits a characteristically slower rate of decay than the 6203 transducer once peak pressure has been reached. The cause of this has not been determined but it is possible that the permanent distortion of the case (to snugly fit the chamber) caused by the pressures involved may be an influence.

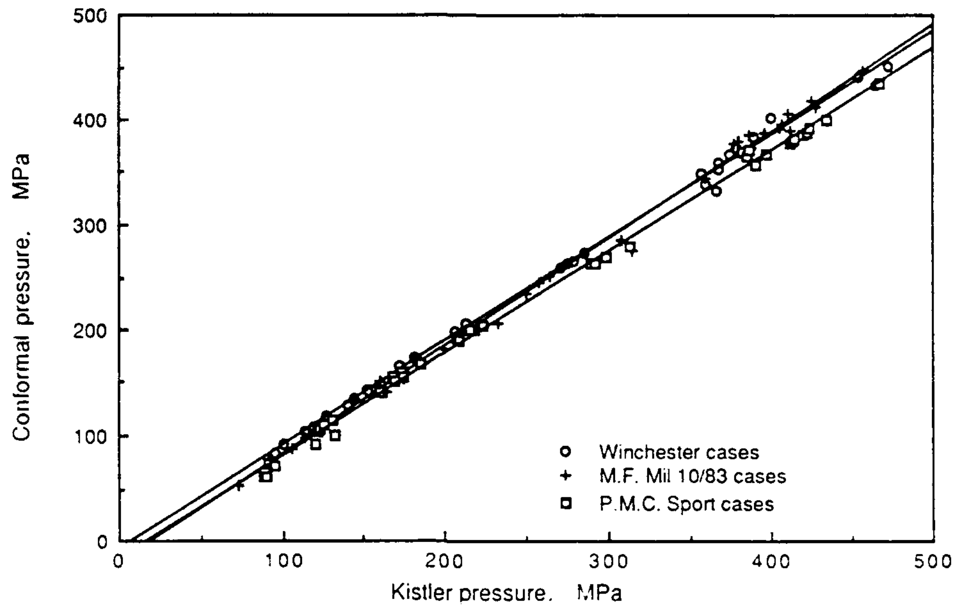

Figure 7: *Conformal versus in-case Kistler pressures (7.62 mm).*

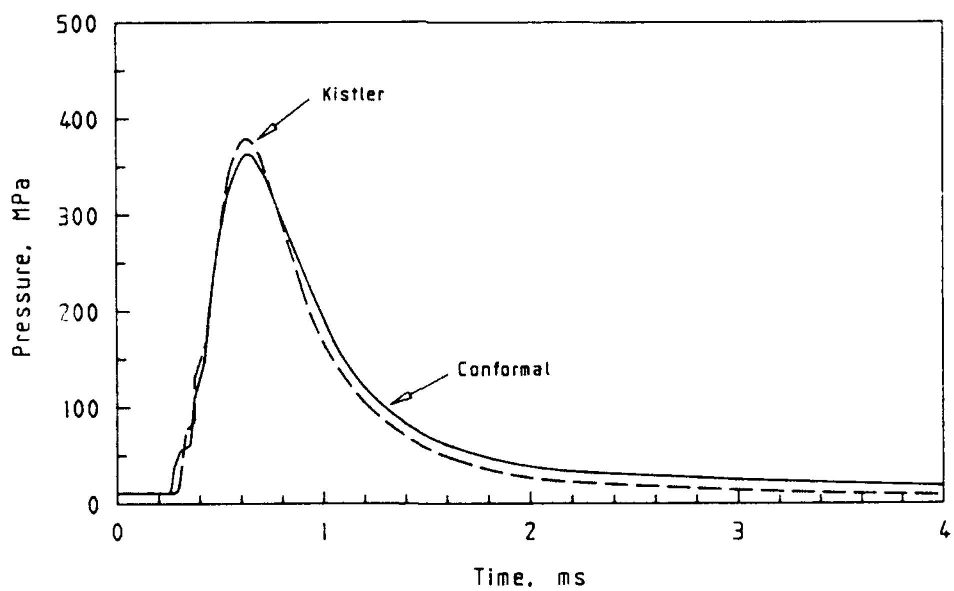

Figure 8: *Conformal and in-case Kistler pressure/time curves (7.62 mm).*

Instead of repeating the test firings with the second conformal transducer it was decided to check its response against the first for just one of the case types. The comparison over a range of pressures is shown in Figure 9 using sensitivity settings determined on the Aminco balance with MF military cases. This shows excellent agreement between the two transducers with very little scatter.

Firings were conducted with 5.56 mm ammunition using in-case Kistler and conformal transducers. An example of the pressure/time curves is shown in Figure 10.

The peak pressures obtained from firings involving two different cases are shown in Figure 11 (graphs of Kistler vs Conformal (S/No. 647) obtained from 5.56 mm test firings are available in Appendix 2). Here the correlation between the conformal transducer and the Kistler is somewhat variable across the pressure range. It is believed that the scatter is the result of poor gas obturation (gas wash was visible on the outside of the cartridge cases) when measuring in-case Kistler pressure.

Experiments were conducted with a Kistler 6203 transducer positioned at the case mouth. In firings of the 7.62 mm ammunition the sensitivity setting of the conformal transducer was fixed at 1.56 pC/bar (Winchester settings) for all cartridge cases to illustrate the effect of case differences on pressure output. Figure 12 shows conformal versus case mouth Kistler graphs for this ammunition.

Figure 13 shows the results obtained with conformal and case mouth Kistler transducers of the 5.56 mm calibre ammunition.

From the data in Figures 12 and 13 it is calculated that an error of up to ± 5% can be expected from conformal transducers at the pressures likely to be encountered in proof testing if calibration for the difference in cartridge cases is not carried out.

From Figure 12, a case mouth Kistler pressure of 350 MPa (a typical pressure generated by a standard filled round fired at ambient temperature) would generate the following conformal pressures:

360 MPa (MF military rounds)
369 MPa (Winchester ammunition)
338 MPa (OFV rounds)
339 MPa (PMC ammunition).

Table 1 shows that the MF and Winchester cases are at the softest end of the hardness scale (Vickers No. of about 20) while the OFV and PMC cases are at the other extreme (Vickers No. figures of about 28). It is therefore considered likely that the variations in pressure recorded are a reflection of case hardness. Thickness is also a variable but since the OFV cases are up to twice the thickness of the PMC cases and they are associated with a near identical pressure reading, it would appear that hardness is the more important factor.

Similarly in Figure 13, the conformal pressures for a Kistler pressure of 350 MPa are:

344 MPa (Winchester ammunition)
350 MPa (AFF ammunition).

Table 2 shows that the softer case yields the higher value of pressure (Vickers No. 31 cf. 25). There is little difference between their thickness but this does not necessarily confirm that hardness is the crucial factor since there is little difference in the pressure measurement anyway.

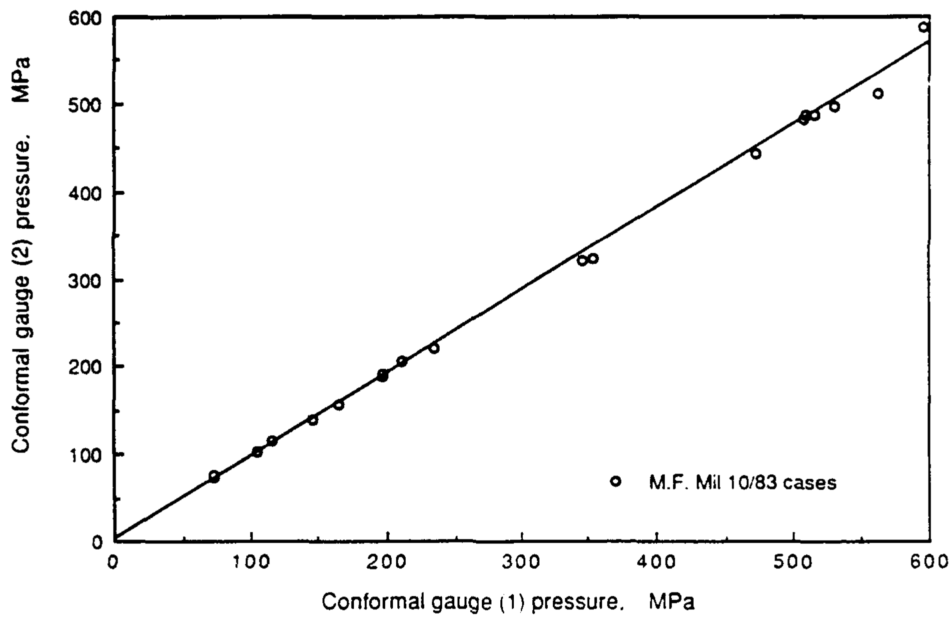

Figure 9: *Comparison of pressure responses for two Conformal transducers (7.62 mm).*

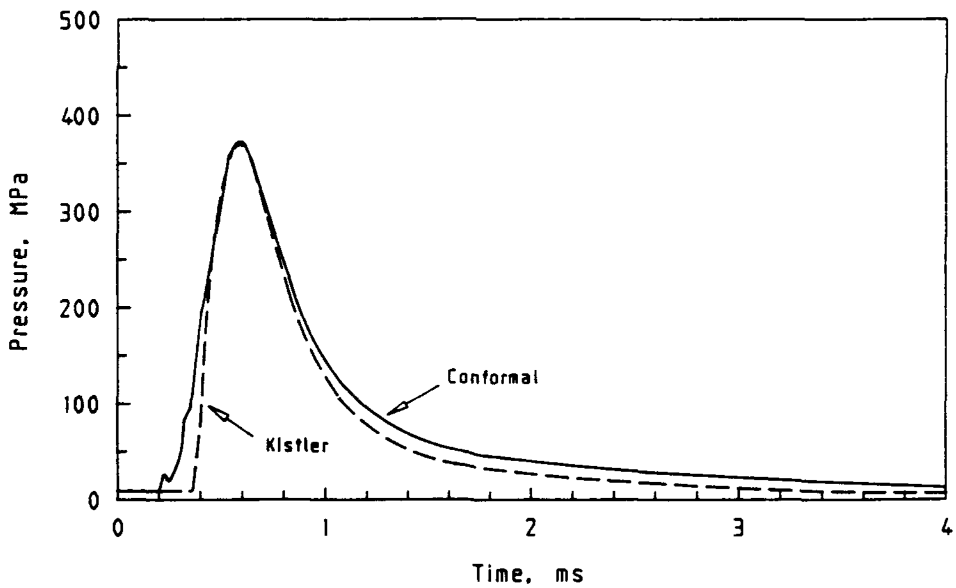

Figure 10: *Conformal and in-case Kistler pressure/time curves (5.56 mm).*

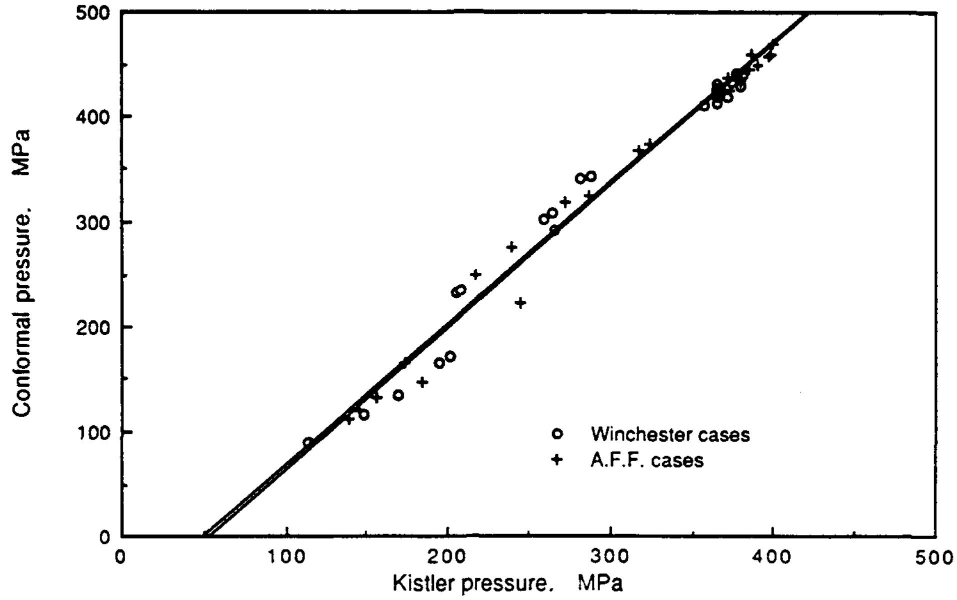

Figure 11: Conformal versus in-case Kistler pressures (5.56 mm).

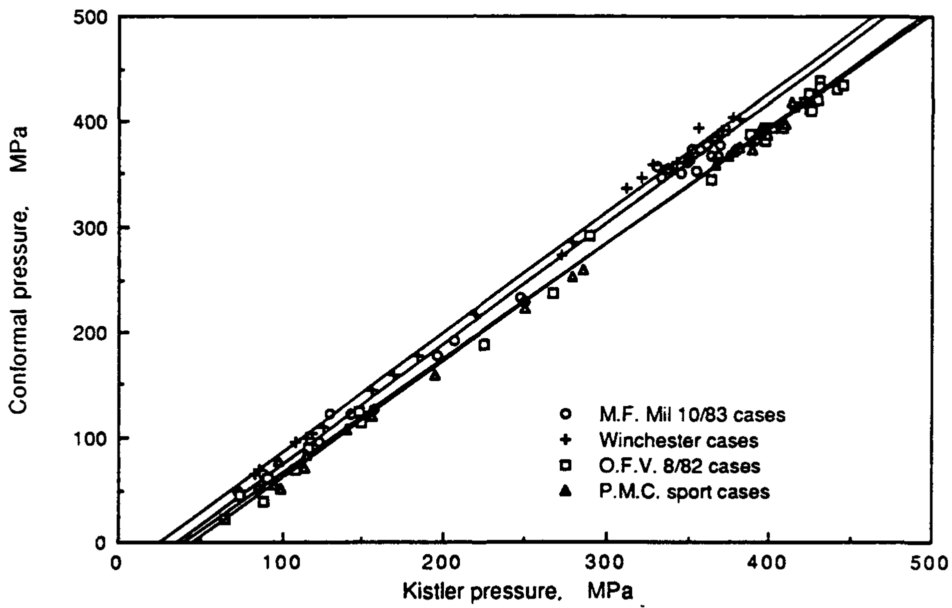

Figure 12: Conformal versus case mouth Kistler pressures (7.62 mm).

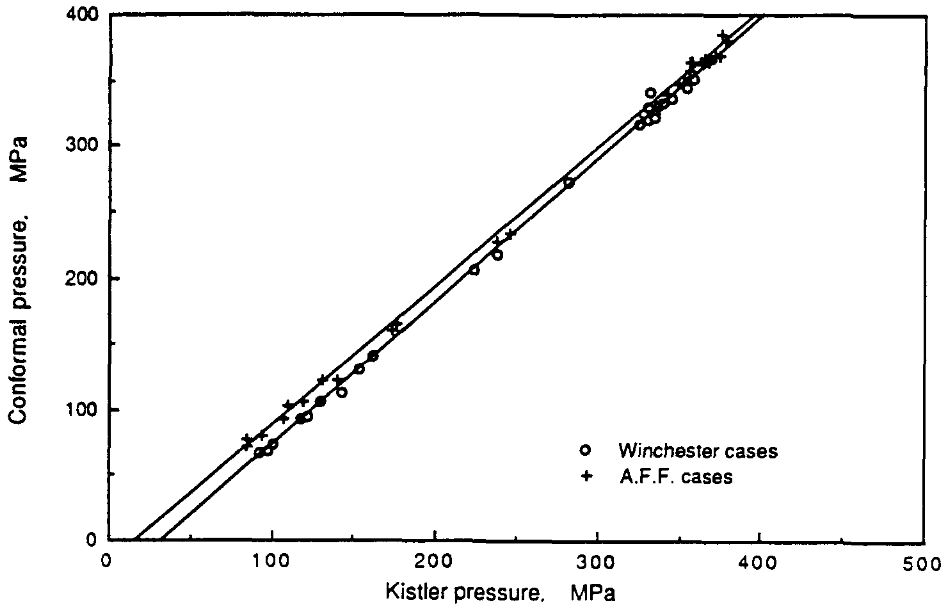

Figure 13: Conformal versus case mouth Kistler pressures (5.56 mm).

4. Conclusions

It can be concluded that in proof testing, PCB type 117B conformal transducers are suitable for the measurement of chamber pressure in both 7.62 mm and 5.56 mm calibre ammunition, provided they are suitably calibrated.

Calibration should preferably be performed in an actual gun firing against a 6203 Kistler positioned at the case mouth location. It is apparent from the results obtained here that cartridge cases which are softer tend to be associated with higher conformal pressures than harder cases presumably because they tend to yield more readily to internal pressure. Of the cartridge cases tested, variations seen were no greater than ± 5% and if this can be tolerated in proof testing then conformal transducers could be used without requiring further calibration for cartridge cases from different manufacturers.

5. Acknowledgements

The authors would like to thank the staff from the Gun Technology and Engineering Support areas for their technical assistance during these experiments. Special thanks to Mr Greg Teague (Gun Technology) and Mr Gary Lampard (EDE) for the technical information they provided.

6. References

1. Change, Nicholas D. (1971). *Conformal piston piezoelectric transducers, a new technique for ballistics pressure chamber measurement*. Report presented October 26, 1971 at Frankford Arsenal Meeting of NATO AC225 Working Party on Chamber Pressure Measurement.

2. Letter to WSRL from PCB. Piezotronics International, Inc. dated 19 October 1982.

3. Kistler Instruments AG. *Operating and service instructions – High pressure quartz transducers - Type 6203.*

4. American Instrument Company. Aminco Pressure Balances (Console Models) Instruction No. 808-B.

Appendix 1

7.62 mm Firing Data

Table 4: *In-case Kistler pressure vs conformal pressure (transducer Serial No. 650)*

Firing No.	Winchester		MF military		PMC Sport	
	Kistler (MPa)	conformal (MPa)	Kistler (MPa)	conformal (MPa)	Kistler (MPa)	conformal (MPa)
1	399.3	402.7	379.8	379.3	397.4	367.5
2	377.8	373.9	157.9	147.6	422.8	391.5
3	374.4	368.0	169.1	153.4	390.5	356.9
4	374.4	368.0	174.1	164.2	419.4	386.1
5	389.1	382.7	159.4	151.0	412.0	377.8
6	368.0	359.7	72.4	53.8	413.6	381.7
7	368.0	353.4	143.7	134.9	413.0	379.8
8	285.9	272.7	126.1	110.0	290.2	263.9
9	271.7	258.6	126.1	110.0	292.8	263.9
10	275.2	263.0	92.9	76.2	313.3	278.6
11	278.6	264.9	113.4	97.8	299.1	269.8
12	213.6	207.0	119.3	104.6	207.7	191.6
13	206.7	197.0	105.3	87.0	208.7	189.6
14	218.6	199.4	427.7	411.5	222.9	204.8
15	212.6	201.9	456.0	446.2	216.0	200.9
16	181.8	173.4	424.7	417.9	167.6	155.2
17	153.0	140.4	359.9	344.1	173.0	158.4
18	174.6	159.2	377.3	377.8	174.5	155.8
19	182.3	172.1	409.6	405.2	169.6	150.6
20	143.7	134.4	386.4	384.7	122.7	107.0
21	151.5	142.2	387.7	373.9	130.5	113.4
22	157.4	143.2	405.1	392.3	184.8	166.7
23	172.5	166.2	411.0	390.5	159.8	141.7
24	119.3	108.7	405.8	395.6	125.1	109.5
25	140.3	129.5	395.2	388.1	120.2	91.9
26	127.6	118.1	265.0	252.0	121.2	105.1
27	127.1	119.3	307.7	285.9	132.0	99.7
28	100.7	91.9	258.0	244.8	89.0	60.3
29	94.3	82.6	314.3	276.5	90.9	73.6
30	94.8	84.1	233.1	205.8	94.8	71.4
31	113.9	104.6	220.4	200.9	89.9	61.2
32	453.1	441.8	250.2	234.7	382.7	370.0
33	472.1	450.3	199.4	181.6	386.6	372.1
34	464.3	432.0	164.2	141.3	384.7	366.3
35	366.1	332.8	186.6	168.1	421.8	388.5
36	359.2	339.2	174.5	152.5	466.3	434.9
37	356.8	349.5	175.0	156.0	434.0	400.8

Table 5: *Conformal pressure (Ser. No. 650) vs conformal pressure (Ser. No. 649) – MF Military 10/83 ammunition*

Firing No.	Conf S/N 650	Conf S/N 649
1	73.4	76.0
2	72.5	73.7
3	104.8	103.8
4	116.5	114.5
5	146.6	139.7
6	164.9	155.7
7	196.1	189.5
8	196.2	190.0
9	235.6	221.3
10	211.1	204.5
11	346.7	320.9
12	354.2	322.6
13	508.4	481.7
14	561.5	512.4
15	516.0	487.7
16	473.7	443.3
17	529.9	498.3
18	509.0	488.3
19	595.6	588.5
20	595.4	588.5

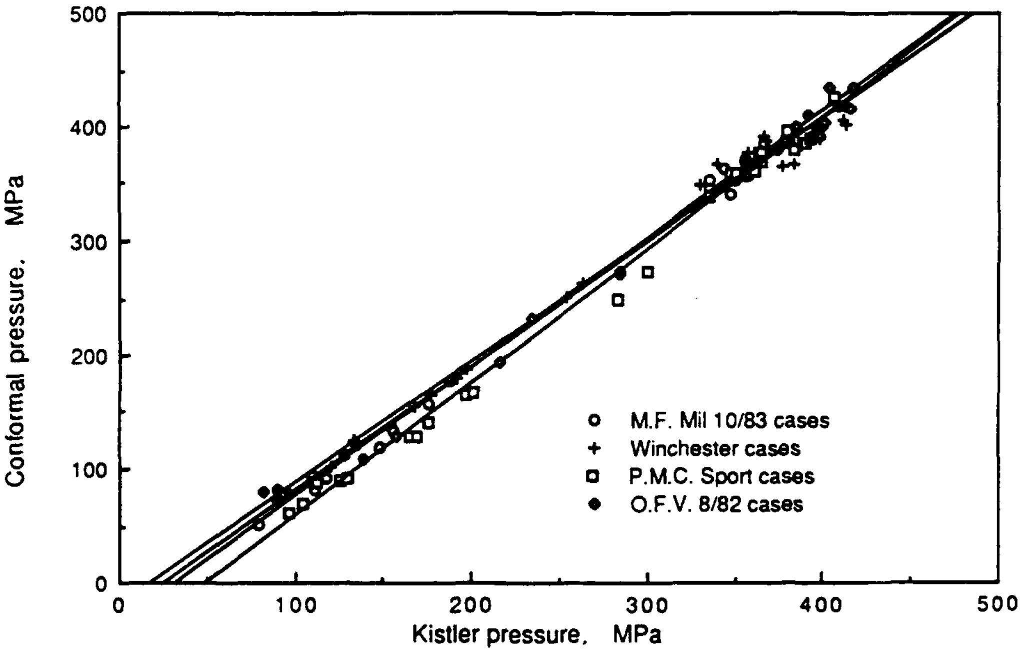

Figure 14: *Conformal (S/No. 649) versus case mouth Kistler pressures (7.62 mm).*

Appendix 2

Graphs of Conformal (S/No. 647) vs Kistler Pressure

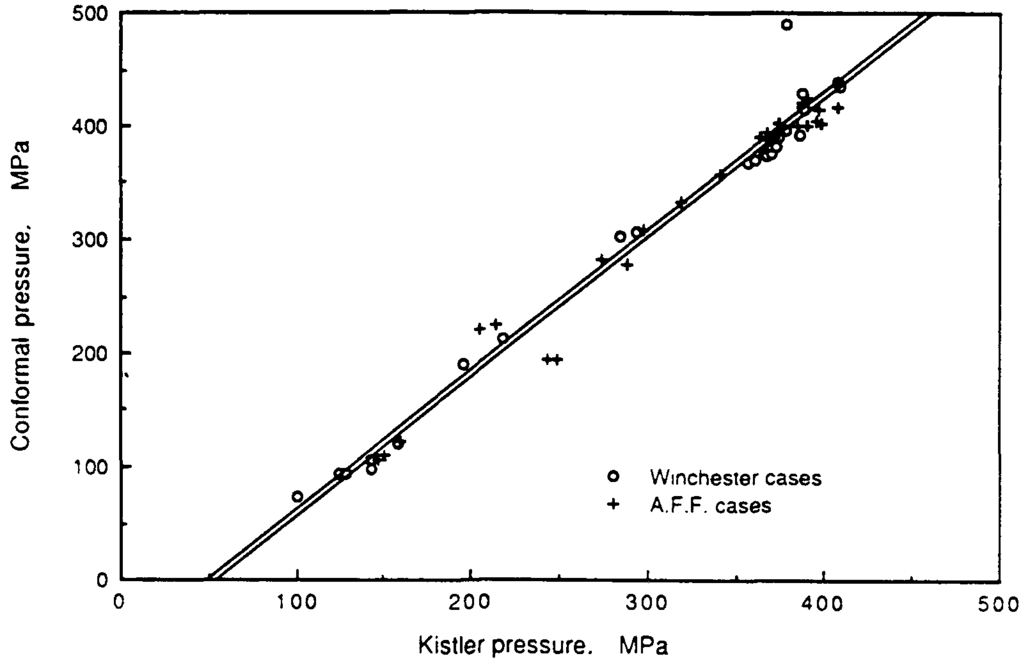

Figure 15: *Conformal versus in-case Kistler pressures (5.56 mm).*

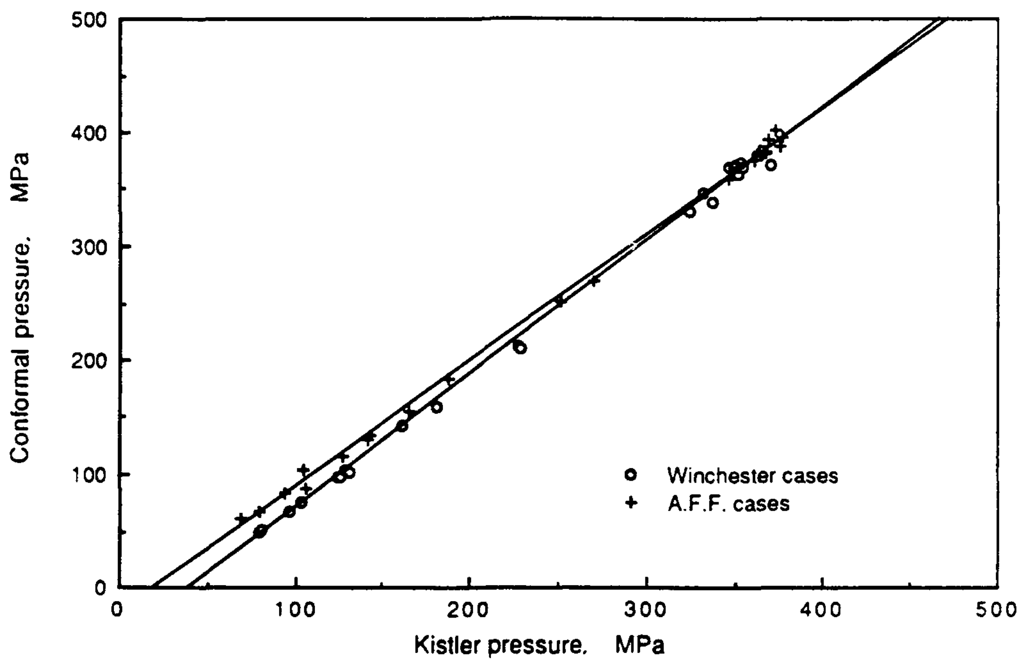

Figure 16: *Conformal versus case mouth Kistler pressures (5.56 mm).*

Appendix 3

Calibration Procedure for 6203 Kistler Transducers

A. General

1. Introduction

The following procedure is to be used whenever Kistler pressure transducer models' 6203 or 6211 are to be calibrated at the piezoelectric transducer calibration facility in Gun Technology. This procedure is based on the operating and service instruction manual issued by Aminco [4] – the manufacturers of the high pressure dead weight tester (HPDWT) – and on local practice.

2. Equipment Required

(a) High pressure dead weight tester (Aminco pressure balance model 47-12915)
(b) Kistler transducer mounting block (built to the specifications in the Kistler manual [3]
(c) Charge amplifier (type PCB, Piezotronics model No. 462B52)
(d) Storage oscilloscope (e.g. Nicolet digital storage CRO)
(e) TNC to BNC lead.

3. Set Up

(a) Set up the HPDWT in the manner described in Section B of this procedure.
(b) Set up the instrumentation as per instructions described in Section C of this procedure.

4. Procedure

(a) Test each transducer three times at the following pressures in ascending order, 105 MPa, 140 MPa, 210 MPa, 280 MPa, 315 MPa, 385 MPa and 420 MPa.
(b) Average the three results from each pressure measurement.
(c) Using the computer program "Kiscal" or the calculation procedure contained in Section D of this procedure, calculate sensitivity, correction factor and percentage deviation.
(d) Record and date results and place with the transducer.

B. High Pressure Dead Weight Tester Operating Procedure

1. Initial Set Up

(a) Fit the transducer in its mounting block as per Kistler's specifications [3].
(b) Connect the transducer mounting block to the output pressure line located at the rear of the HPDWT.

(c) Close all six valves by rotating the console mounted knobs clockwise.
(d) Set "Weight Raise" valve to "down", i.e. horizontal.
(e) Insert "weight select rod" into the hole immediately above the 105 MPa weight.
(f) Turn on air and power lines to the HPDWT.

2. *Charging the Pressure Intensifier*

(a) Ensure all valves are closed.
(b) Open valves "3" and "6" (anticlockwise).
(c) Work pump until the dial gauge reads a steady 15 000 psi (100 MPa).

NOTE: If the intensifier pressure goes above 15 000 psi gently crack open valve "5" to make gauge read 15 000 psi. Close valve "5".

3. *Making a Measurement*

(a) Set the quick release valve lever to the end stop.
(b) Set up or arm the instrumentation as required.
(c) Open valves 1, 2 and 4.
(d) After selecting the desired weights, i.e. start at 105 MPa, raise the unused weights.
(e) Operate the pump until the dead weight tester is balanced.

NOTE: If the tester should become over-balanced gently crack open valve "6" then rebalance.

(f) Close valve "2" and ensure the tester is still balanced.

NOTE: Before the first measurement of the day the tester should be left balanced and oscillating for about 15 minutes.

(g) Release Lever valve. A measurement should have been recorded.
(h) Reset lever valve to the end stop position.
(i) Lower the weights.
(j) Open valve "2".
(k) Select new weight if required.
(l) Repeat from 3(d).

4. *Closing Down*

(a) Close all valves.
(b) Lower the weights and position weight selector bar into 105 MPa.
(c) Gently crack open valves "5" and "6".
(d) Open all valves.
(e) Remove the transducer mounting block from the HPDWT.
(f) Remove the transducer from the mounting block.

C. Instrumentation Operating Procedure

1. Charge Amplifier

(a) Set the charge amplifier gain to unity or 0.999.
(b) Ground the input and select short time constant, switch power on.
(c) Connect the amplifier input to the gauge and the output to the storage oscilloscope.

2. Storage Oscilloscope

(a) Set the time base to 1 ms/div or 10 ms/div range.
(b) Set the vertical gain to 0.5 V/div or 2 V/div range.
(c) Set the trigger to AC couple, negative going and to the channel that the input is connected.
(d) Arm the trigger as required.
(e) Use the cursor to record measurements.

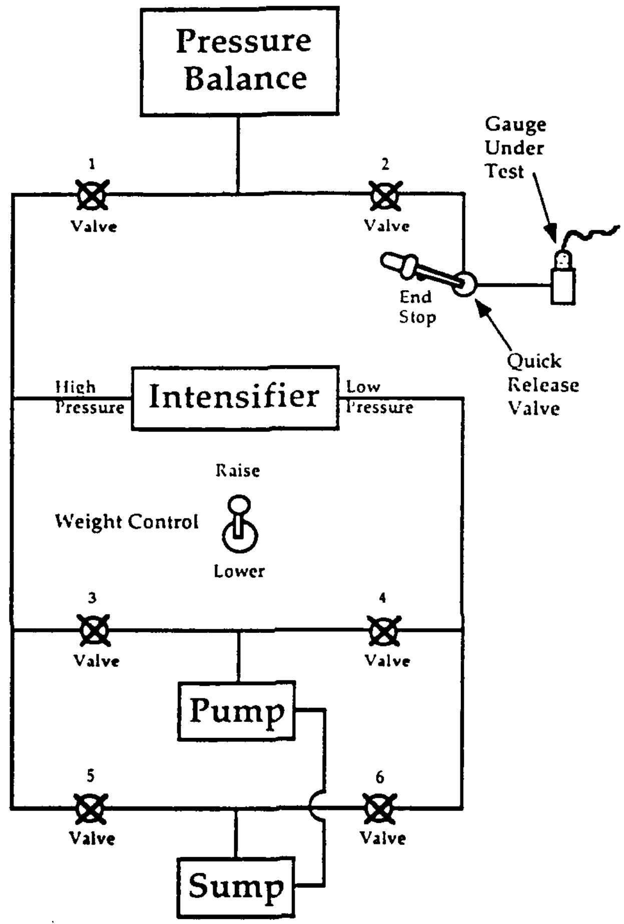

Figure 17: Block diagram of the Aminco High Pressure Dead Weight Tester.

D. *Calculation Procedure*

1. *Data Required* $V_{(n)}$

Vout @ Pressure (MPa)

For 105, 140, 210, 280, 315, 385 and 420 MPa

i.e. $V_{(1)}$ @ $P_{(1)}$ (105 MPa)
$V_{(2)}$ @ $P_{(2)}$ (140 MPa)
: : :
$V_{(7)}$ @ $P_{(7)}$ (420 MPa)

2. *Average Sensitivity*

$$\text{Ave Sens} = \frac{\sum_1^7 V_{(n)}}{\sum_1^7 P_{(n)}} \quad \text{i.e.} \quad \frac{V_{(1)} + V_{(2)} + \ldots V_{(7)}}{P_{(1)} + P_{(2)} + \ldots P_{(7)}}$$

3. *Correction Factor*

$$\text{Correction Factor} = \frac{7\sum_1^7 P_{(n)} \cdot V_{(n)} - \sum_1^7 P_n \cdot \sum_1^7 V_n}{\sqrt{7\sum_1^7 P_{(n)}^2 - \left(\sum_1^7 P_{(n)}\right)^2} \cdot \sqrt{7\sum_1^7 V_{(n)}^2 - \left(\sum_1^7 V_{(n)}\right)^2}}$$

4. *Sensitivity and Deviation at Pressure P(n) in MPa*

$$\text{Sensitivity } S_{(n)} = \frac{V_{(n)}}{P_{(n)}}$$

$$\text{Percent Deviation \%D} = \frac{100\, P_{(n)}\left(V_{(n)}\ \ P_{(n)} - \sum_1^7 V_{(n)}\ \ \sum_1^7 P_{(n)} \right)}{V_{(7)}}$$

5. HP 85 Program to Calculate Factors

Program Name: KISCAL

```
10  DIM M(7), S$[6], V(7), D$[8]
20  IMAGE "AVE SENS = - ", D.DDD
30  IMAGE "CORR FACT =", Z.DDD
40  IMAGE "S(",D,")=-", D.DDD," %D=", Z.DDDD, "@", DDD, "MPa"
50  M(1) = 105
60  M(2) = 140
70  M(3) = 210
80  M(4) = 280
90  M(5) = 315
100 M(6) = 385
110 M(7) = 420
120 DISP "ENTER GATE" @ INPUT D$
130 DISP "ENTER GAUGE SER NO" @ INPUT S$
140 DISP "ENTER CHARGE AMP SETTING" @ INPUT C
150 PRINT "SER No:   "; S$,"  "; D$
160 PRINT
170 V=0 @ P=0 @ X=0 @ Y=0 @ Z=0
180 FOR I=1 TO 7
190 DISP "ENTER Vout FOR"; M(I);"MPa" @ INPUT V(I)
200 V=V(I) + V
210 P=P+M(I)
220 X=X+M(I)*V(I)
230 Y=Y+V(I)*V(I)
240 Z=Z+M(I)*M(I)
250 NEXT J
260 PRINT USING 20 ; V/P
270 PRINT USING 30 ; (7*X-p*V)/(7*Z-P^2)^.5*(7*Y-V^2)^.5)
280 PRINT
290 FOR I=1 TO 7
300 PRINT USING 40 ; I,V(I)/M(I) , 100*M(I)&(V(I)/M(I)-V/P)/V(7), M(I)
310 NEXT I
320 PRINT
330 PRINT
340 PRINT
350 PRINT
360 END
```

SECURITY CLASSIFICATION OF THIS PAGE **UNCLASSIFIED**

REPORT NO.	AR NO.	REPORT SECURITY CLASSIFICATION
MRL-TN-608	AR-006-873	Unclassified

TITLE

A comparison between conformal transducers and Kistler 6203 transducers for measuring chamber gas pressure in small arms ammunition

AUTHOR(S)	CORPORATE AUTHOR
C. Wachsberger and S. Forbes	DSTO Materials Research Laboratory PO Box 50 Ascot Vale Victoria 3032

REPORT DATE	TASK NO.	SPONSOR
December, 1992	ARM 40/015	Army

FILE NO.	REFERENCES	PAGES
G6/4/8-4284	4	27

CLASSIFICATION/LIMITATION REVIEW DATE	CLASSIFICATION/RELEASE AUTHORITY
	Chief, Explosives Ordnance Division

SECONDARY DISTRIBUTION

Approved for public release

ANNOUNCEMENT

Announcement of this report is unlimited

KEYWORDS

Piezoelectric transducers | Gas pressure measurement | Cartridges
Calibration

ABSTRACT

Today, copper crusher gauges have largely given way to quartz piezoelectric transducers for the measurement of pressure in small calibre gun firings. Recent developments in piezoelectric transducers have resulted in the creation of the conformal gauge. This device, fitted semi-permanently in the proof barrel, measures gas chamber pressure by directly sensing the resultant forces on the cartridge case. This report gives results of comparisons made between PCB type 117B conformal transducers and NATO approved Kistler 6203 transducers for the measurement of pressure of 7.62 mm and 5.56 mm calibre NATO ammunition in proof barrels.

A Comparison between Conformal Transducers and Kistler 6203 Transducers
for Measuring Chamber Gas Pressure in Small Arms Ammunition

C. Wachsberger and S. Forbes

(MRL-TN-608)

DISTRIBUTION LIST

Director, MRL
Chief, Explosives Ordnance Division
Mr L. Sheppard
Mr C. Wachsberger
Mr S. Forbes
MRL Information Service

Chief Defence Scientist (for CDS, FASSP, ASSCM) (1 copy only)
Director, Surveillance Research Laboratory
Director (for Library), Aeronautical Research Laboratory
Director, Electronics Research Laboratory
Scientific Adviser, Defence Intelligence Organisation
OIC Technical Reports Centre, Defence Central Library
Officer in Charge, Document Exchange Centre (8 copies)
Army Scientific Adviser, Russell Offices
Air Force Scientific Adviser, Russell Offices –
Navy Scientific Adviser, Russell Offices - data sheet only
Scientific Adviser, Defence Central
Director-General Force Development (Land)
Senior Librarian, Main Library DSTOS
Librarian, MRL Sydney
Librarian, H Block
UK/USA/CAN ABCA Armies Standardisation Rep. C/- DGAD(NSO) (8 copies)
Librarian, Australian Defence Force Academy
Counsellor, Defence Science, Embassy of Australia - data sheet only
Counsellor, Defence Science, Australian High Commission - data sheet only
Scientific Adviser to DSTC, C/- Defence Adviser - data sheet only
Scientific Adviser to MRDC, C/- Defence Attache - data sheet only
Head of Staff, British Defence Research and Supply Staff (Australia)
NASA Senior Scientific Representative in Australia
INSPEC: Acquisitions Section Institution of Electrical Engineers
Head Librarian, Australian Nuclear Science and Technology Organisation
Senior Librarian, University of Tasmania
Library - Exchange Desk, National Institute of Standards and Technology, US
Exchange Section, British Library Document Supply Centre
Periodicals Recording Section, Science Reference and Information Service, UK
Library, Chemical Abstracts Reference Service
Engineering Societies Library, US
Documents Librarian, The Center for Research Libraries, US
Resources Librarian, Dept. of Scientific and Industrial Research, NZ

Director, Quality Assurance Armament, Melbourne
Commanding Officer, Proof and Experimental Establishment, Graytown, PO Box 23, Nagambie, Vic. 3608
Commanding Officer, Proof and Experimental Establishment, Port Wakefield, SA 5550
QA Division, HQ Log Command, GPO Box 1932R, Melbourne, Vic 3001 (Attention: Mr P. Buchler)

DISTRIBUTION LIST
(Continued)

(MRL-TN-608)

Commander, Engineering Development Establishment, PO Box 30, Ascot Vale
Superintendent, Labs and Services, EDE
Mr John Logan, Small Arms Group, EDE
General Manager, ADI Mulwala Facility, Private Bag No. 1, Mulwala NSW 2647
Mr Rod Sissons, ADI, Private Bag No. 1, Mulwala NSW 2647
General Manager, ADI St Marys Facility, PO Box 196, St Marys NSW 2760
General Manager, ADI Footscray Facility, Private Bag No. 1, Footscray 3011
Mr Philip Mibus, ADI Footscray Facility, Private Bag No. 1, Footscray 3001
Dr Stuart Stephenson, EOD Salisbury
Dr Bill Jolley, EOD Salisbury
Dr Alan Rye, EOD Salisbury
Mr Juan Hooper, EOD Salisbury
Dr Anna Wildegger-Gaissmaier, EOD Salisbury